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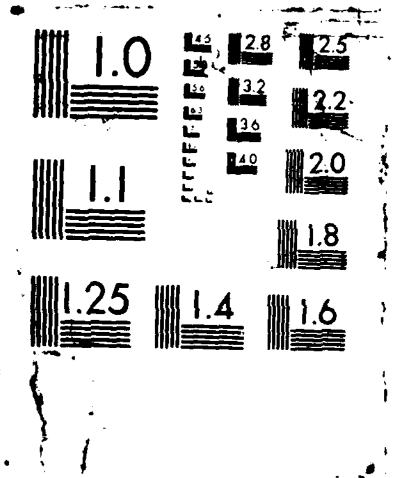
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FINAL REPORT FOR CONTRACT N00014-84-K-0643

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for Stanford University

Final Report for Contract N00014-84-K-0643

In 1984 we proposed to the Office of Naval Research a program of research to demonstrate the feasibility of a compact and efficient accelerator capable of producing very high quality electron beams suitable for Free Electron Laser (FEL) systems. It was assumed that the injector for this accelerator would incorporate harmonic acceleration to guarantee high beam quality and that the accelerator itself would utilize beam recirculation both for energy doubling and for energy recovery. The proposed program was to extend over a period of three years at a total cost of $ 1,009,591.

The major activities in the proposed three-year program are listed below:

1. Design a single-cell accelerating cavity suitable for a modest power FEL system, and demonstrate by operation of a prototype cavity the feasibility of achieving gradients exceeding 6 MeV/m.
2. Find a geometry for a single harmonic cavity that is suitable for use in the harmonic injector system. Operate a prototype harmonic cavity at high gradient.
3. Design an injector system incorporating harmonic acceleration and magnetic bunching.
4. Construct and test a prototype injector system incorporating harmonic acceleration with an output energy of approximately 3 MeV.
5. Study the feasibility of a compact and efficient accelerator suitable for FEL systems that utilizes beam recirculation both for energy doubling and for energy recovery.

In the first year of this program (August 1, 1984 to July 31, 1985) funding

in the amount of $ 155,093 was provided by the Office of Naval Research. In the second year, an additional $ 50,000 was provided and then the program was terminated. Despite the limited funds available we were able to carry out a significant part of the program. Clearly those parts of the program that required large capital investment were no longer possible to attempt. Our accomplishments are listed below:

1. Single-cell[1] and two-cell[2] generating structures suitable for modest power FEL systems were designed. Two single-cell 1300 MHz structures were fabricated from standard grade (RRR=30) Wah Chang niobium sheet and tested. At a temperature of 2 K these structures achieved gradients of 5.2 MeV/m and 5.1 MeV/m at the first cool down. The gradients achieved in these structures were limited by thermal breakdown caused by localized defects and the relatively low thermal conductivity of the niobium. These cavities were subsequently treated with titanium as an external getter for interstitial impurities, thereby increasing the thermal conductivity of the niobium by a large factor. After titanium treatment the structures achieved gradients of 8.0 MeV/m and 8.2 MeV/m, values limited by electron field emission.[2]

2. In our studies of harmonic cavities suitable for use in the harmonic injector system we considered the possibility of establishing both the fundamental accelerating field and the harmonic decelerating field in the same cavity.[3]

At typical electron beam injection energies of 100 keV it is important to have spatial overlap of the fundamental and harmonic fields. At higher energies spatial separation of the fundamental and harmonic fields is not only possible, but even superior.[2] We have shown that for an electron beam injection energy of 300

keV, establishing the fundamental and harmonic fields in separate accelerating structures is possible at 1300 MHz (and 3900 MHz) if the structures consist of one or two cells operating at approximately 7.5 MeV/m.[4] A single-cell harmonic structure has been designed but the expense of purchasing microwave equipment at the harmonic frequency made it impossible to fabricate and test a structure with the available funds.

3. An injector system utilizing an electron gun at 300 keV, a pair of two- cell accelerating structures for the fundamental and a single-cell third harmonic structure located between the fundamental structures has been designed. Computer calculations of the output electron beam parameters including the effects of rf dynamics and space charge have been carried out[4] using PARMELA.[5] For an electron bunch charge of 1 nC a normalized transverse emittance less than 10 π mm mr is expected from our harmonic injector system. At sufficiently high energy one should be able to compress the electron bunch magnetically and achieve peak currents greater than 100 A. The resulting beam brightness: $B = 2\pi^2 I_p/\epsilon_n^2$ would be $10^8 A/cm^2 rad^2$, a value comparable to that available from storage rings.
4. No attempt was made to construct and test a prototype injector system with the limited funds available.
5. Subsequent to the termination of this contract a very compact, and efficient accelerator that utilizes beam recirculation for energy doubling and for energy recovery has been designed.[6] This accelerator represents a very attractive driver for a versatile FEL system.

The work carried out in this research program has been described in four papers presented at scientific conferences on accelerator physics and Free Electron

Lasers. One of these was an invited paper. The Ph.D. thesis of Carl Hess was based principally on work supported by this program.

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